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RESEARCH MEMORANDUM

AN APPROXIMATION TO THE EFFECT OF GEOMETRIC DIHEDRAL ON THE ROLLING MOMENT DUE TO SIDESLIP FOR WINGS AT TRANSONIC AND SUPERSONIC SPEEDS

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RESEARCH MEMORANDUM

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SUMMARY

A simple geometric relation has been found, by use of which the effect of geometric dihedral on the rolling moment due to sideslip at transonic and supersonic speeds may be estimated for wings if either the damping in roll or the rolling moment due to differential wing incidence is known. No data are available for use in a direct check of the proposed method at transonic speeds. Theoretical data are available, however, for checks at supersonic speeds and experimental data are available for checking estimated ratios of damping in roll to rolling moment due to differential wing incidence at transonic and supersonic speeds. It is believed that these checks justify the use of the proposed approximation.

INTRODUCTION

A recent summary of methods for estimating lateral stability derivatives (reference 1) calls attention to the lack of experimental data at transonic and supersonic speeds for all derivatives except possibly the damping in roll (or rolling moment due to rolling) (references 2 to 10.)

Linear-theory calculations are available for several derivatives at supersonic speeds and, among these, references 11 and 12 treat the effect of geometric dihedral on the rolling moment due to sideslip for narrow and wide triangular wings.

The present paper offers a simple geometric relation whereby the existing information on damping in roll may be used to estimate the effect of geometric dihedral on the rolling moment due to sideslip. Values for the dihedral effect calculated from this approximation are compared with existing linear-theory values.

SYMBOLS

C_l rolling-moment coefficient $\left(\frac{L}{qSb}\right)$

L rolling moment, pound-feet

q dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$ pounds per square foot

S wing area, square feet

b wing span, feet

ρ mass density of air, slugs per cubic foot

V velocity, feet per second

$\frac{pb}{2V}$ wing-tip helix angle, radians

p rate of roll, radians per second

β angle of sideslip, degrees

i_w differential wing incidence, degrees per half-wing

Γ dihedral angle, degrees per half-wing

λ taper ratio $\left(\frac{\text{Tip chord}}{\text{Root chord}}\right)$

α_N angle of attack in plane normal to half-wing for side-slipping wing with dihedral, degrees (see reference 13)

$$C_{l_p} = \frac{dC_l}{d\left(\frac{pb}{2V}\right)}$$

$$C_{l_\beta} = \frac{dC_l}{d\beta}$$

$C_{l_{i_w}} = \frac{dC_l}{di_w}$

$\left.\begin{matrix} f_1 \\ f_2 \end{matrix}\right\}$ numerical functions relating C_{l_β}/Γ and $C_{l_{i_w}}$ to C_{l_p}

METHOD

Basis

The basis for the proposed method of estimating the effect of dihedral on the rolling moment due to sideslip is that:

(a) For a wing with dihedral, sideslip imposes a rectangular distribution of angle of attack over each half-wing and the angle of attack is equal in magnitude but opposite in sign for the two half-wings as in the case of differential wing incidence (reference 13).

(b) For wings with differential incidence, reference 14 shows that a reasonable approximation to the rolling effectiveness $\frac{d\left(\frac{pb}{2V}\right)}{di_w}$ $\left(\text{or the ratio } \frac{C_{l_{i_w}}}{C_{l_p}}\right)$ can be obtained from simple strip theory.

(c) Therefore, the effect of dihedral on the rolling moment due to sideslip should also be subject to reasonable approximation by use of simple strip theory provided one knows values of $C_{l_{i_w}}$ or C_{l_p} for the wing under consideration.

Derivation

Reference 14 gives the ratio of rolling moments due to rolling and those due to differential wing incidence as:

$$\frac{d\left(\frac{pb}{2V}\right)}{di_w} = \frac{2}{57.3}\left(\frac{1 + 2\lambda}{1 + 3\lambda}\right) \tag{1}$$

but since

$$\frac{d\left(\frac{pb}{2V}\right)}{di_w} = \frac{C_{l_{i_w}}}{C_{l_p}} \tag{2}$$

then

$$C_{l_{i_w}} = \frac{2}{57.3}\left(\frac{1 + 2\lambda}{1 + 3\lambda}\right)C_{l_p} = f_1 C_{l_p} \tag{3}$$

Reference 13 shows, that for wings with dihedral, the half-wing angle-of-attack loading in sideslip is similar to that produced by differential wing incidence. The magnitude of the angle-of-attack loading is

$$i_w = \alpha_N = \beta \sin \Gamma \tag{4}$$

or

$$\frac{di_w}{d\beta} = \sin \Gamma \tag{5}$$

then

$$C_{l_\beta} = C_{l_{i_w}} \frac{di_w}{d\beta} \tag{6}$$

and with the assumption that for small angles $\sin \Gamma$ equals $\frac{\Gamma}{57.3}$

$$C_{l_\beta} = C_{l_{i_w}} \frac{\Gamma}{57.3} \tag{7}$$

From equations (3) and (7)

$$C_{l_\beta} = \frac{2}{57.3}\left(\frac{1 + 2\lambda}{1 + 3\lambda}\right) C_{l_p} \frac{\Gamma}{57.3} \tag{8}$$

or

$$\frac{C_{l_\beta}}{\Gamma} = \frac{2}{(57.3)^2}\left(\frac{1 + 2\lambda}{1 + 3\lambda}\right)C_{l_p} = f_2 C_{l_p} \tag{9}$$

and equation (7) converts to

$$\frac{C_{l_\beta}}{\Gamma} = \frac{C_{l_{i_w}}}{57.3} \tag{10}$$

where all angles except $\frac{pb}{2V}$ are in degrees.

The numerical functions f_1 and f_2 in equations (3) and (9) are plotted against taper ratio λ in figure 1.

DISCUSSION

There appears to be no experimental information available at transonic and supersonic speeds to allow a check of equations (9) and (10). Equation (3) for calculating $\frac{dC_l}{di_w}$, however, is considered to be adequately checked by the experimental data presented in reference 14. Values of $\frac{C_{l_\beta}}{\Gamma}$ calculated from linear theory for triangular wings at supersonic speeds are given in reference 12 and the linear-theory values of $\frac{C_{l_\beta}}{\Gamma}$ for rectangular wings at supersonic speeds were obtained as a limiting case (differential deflection of full-span full-chord flaps or differential wing incidence) from reference 15. These theoretical results are shown in figure 2 along with values calculated from equation (9) by using C_{l_p} from linear theory and also using experimental data for C_{l_p} of thin wings from reference 10. In general, the agreement between linear theory and the present approximation is fairly good for either theory or experiment for C_{l_p}. The agreement between values of C_{l_β}/Γ calculated from theoretical and experimental values of C_{l_p} is simply a reflection of the agreement between theory and experiment for C_{l_p} of thin wings.

The agreement of the present approximations with experiment for $\frac{C_{l_{i_w}}}{C_{l_p}}$ and with supersonic linear theory for $\frac{C_{l_\beta}}{\Gamma}$ are felt to be sufficiently good to justify the use of equations (9) and (10).

Although not generally applicable nor intended for use at subsonic speeds, it is interesting to note that the use of equation (9) does check fairly well with theory for the particular case of the narrow triangle (reference 11). This comparison is essentially a comparison of the slopes through zero of the two curves in figure 2(a).

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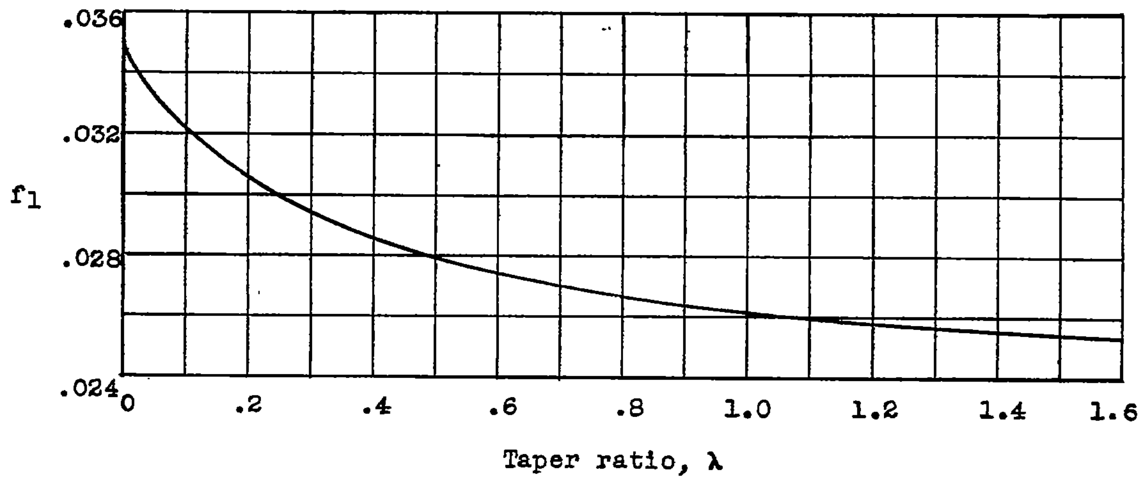
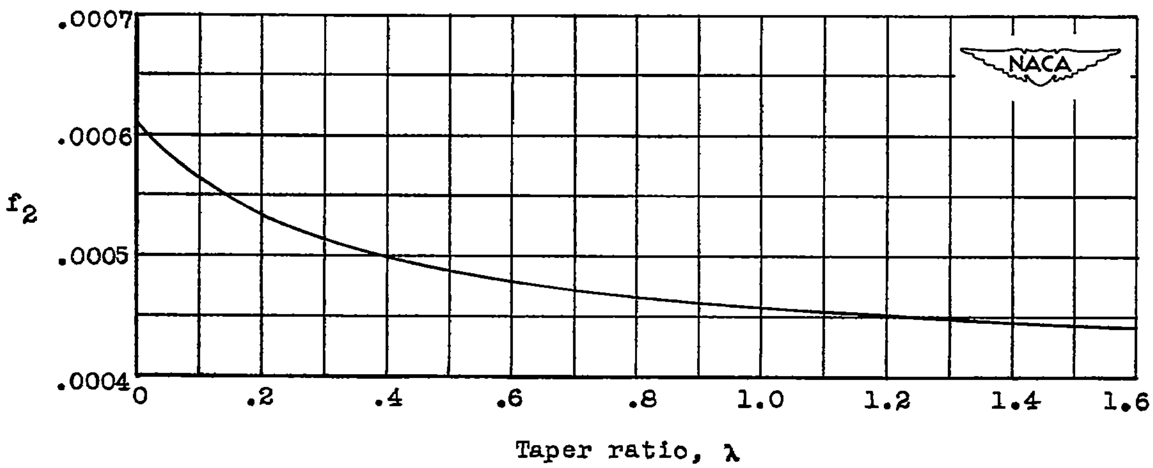
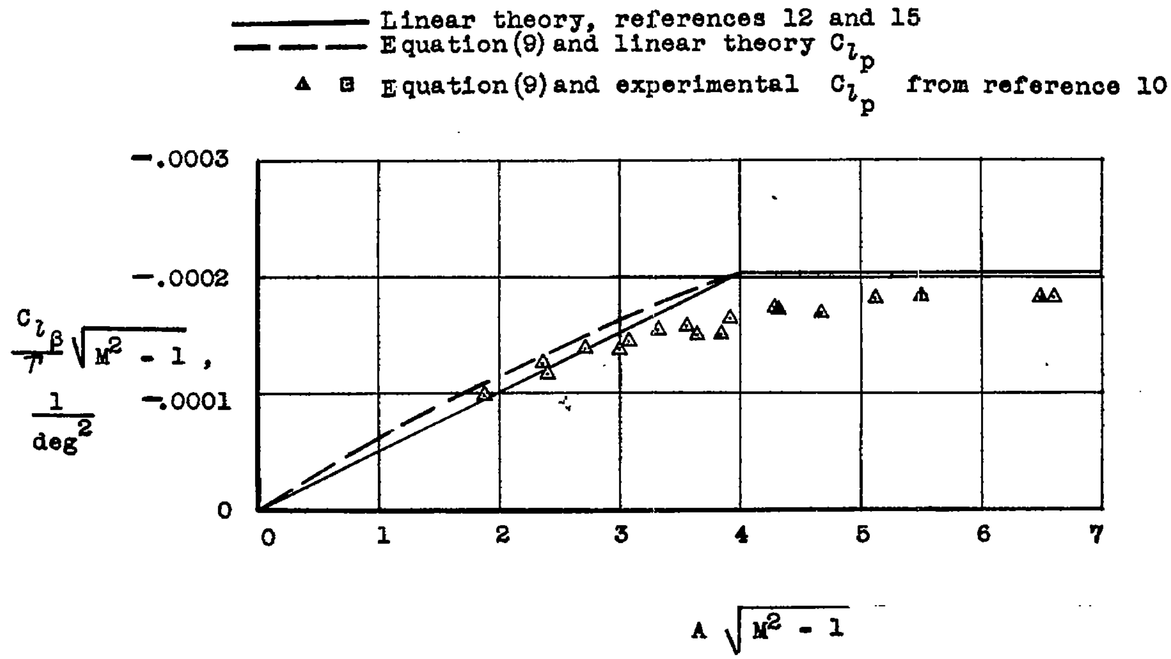


(a) $C_{l_{i_W}} = f_1 C_{l_p}$, equation (3).

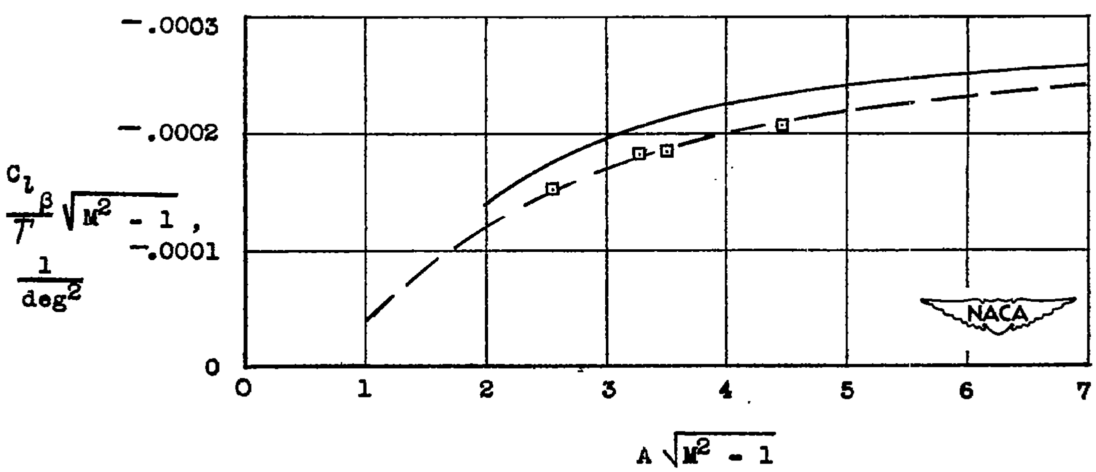


(b) $\dfrac{C_{l_\beta}}{\Gamma} = f_2 C_{l_p}$, equation (9).

Figure 1.- Variation with taper ratio of the functions relating $C_{l_{i_W}}$ and $\dfrac{C_{l_\beta}}{\Gamma}$ to C_{l_p}.



(a) Triangular wings.



(b) Rectangular wings.

Figure 2.- Comparison of linear theory and present approximation for effect of geometric dihedral on rolling moment due to sideslip.

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